Collider-Accelerator Department Overview

Presented to

RHIC Facility Annual Science and Technology Review

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July 6, 2005

BROOKHAVEN NATIONAL LABORATORY

Office of Science
U.S. DEPARTMENT OF ENERGY

COLLIDER-ACCELERATOR DEPARTMENT

Circa June 2005

Mission: "To develop, improve and operate the suite of particle/heavy ion accelerators used to carry out the program of accelerator-based experiments at BNL; support of the experimental program including design, construction and operation of the beam transports to the experiments, plus support of detector and research needs of the experiments; to design and construct new accelerator facilities in support of the BNL and national missions. The C-A Department supports an international user community of over 1500 scientists. The Department performs all these functions in an environmentally responsible and safe manner under a rigorous conduct of operations approach."

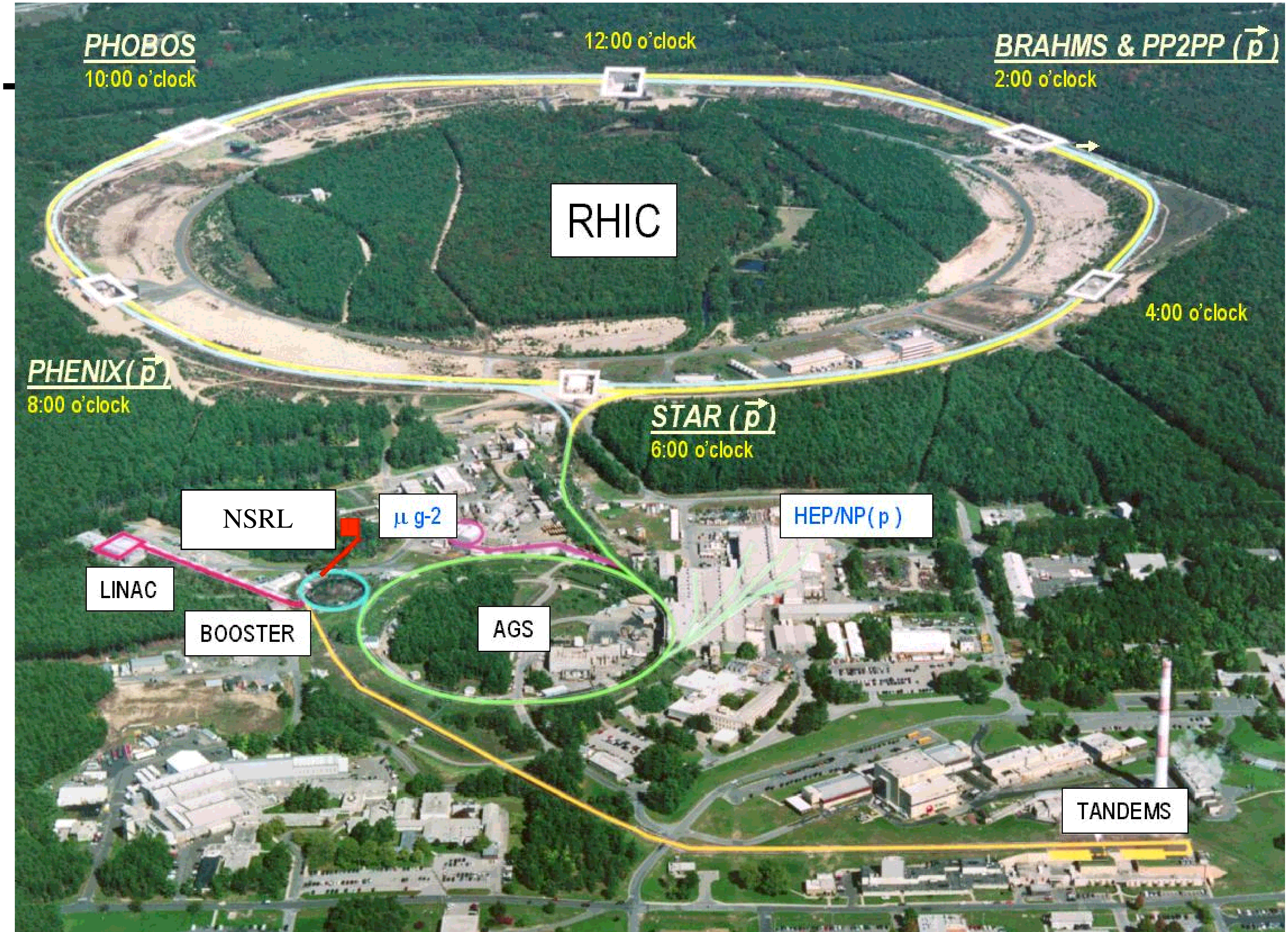
Staff: The Collider-Accelerator Department headcount is:

	Total	NP*	SNS	NASA	Other
Ph.D. Scientists	49	48	0	1	0
Postdoctoral Fellows	3	3	0	0	0
Engineers/Professional	132	126	0	4	2
Designers/Technicians	186	175	0	7	4
Admin./Clerical	19	17	0	2	0
Totals	389	369	0	14	6

SNS Project ended as of March 31, 2005; 25 FTEs charged in FY 2005.
*Does not include ~26 Magnet Division employees charged to NP.
Additional support ~13 FTEs are purchased as Laboratory assigned trades.

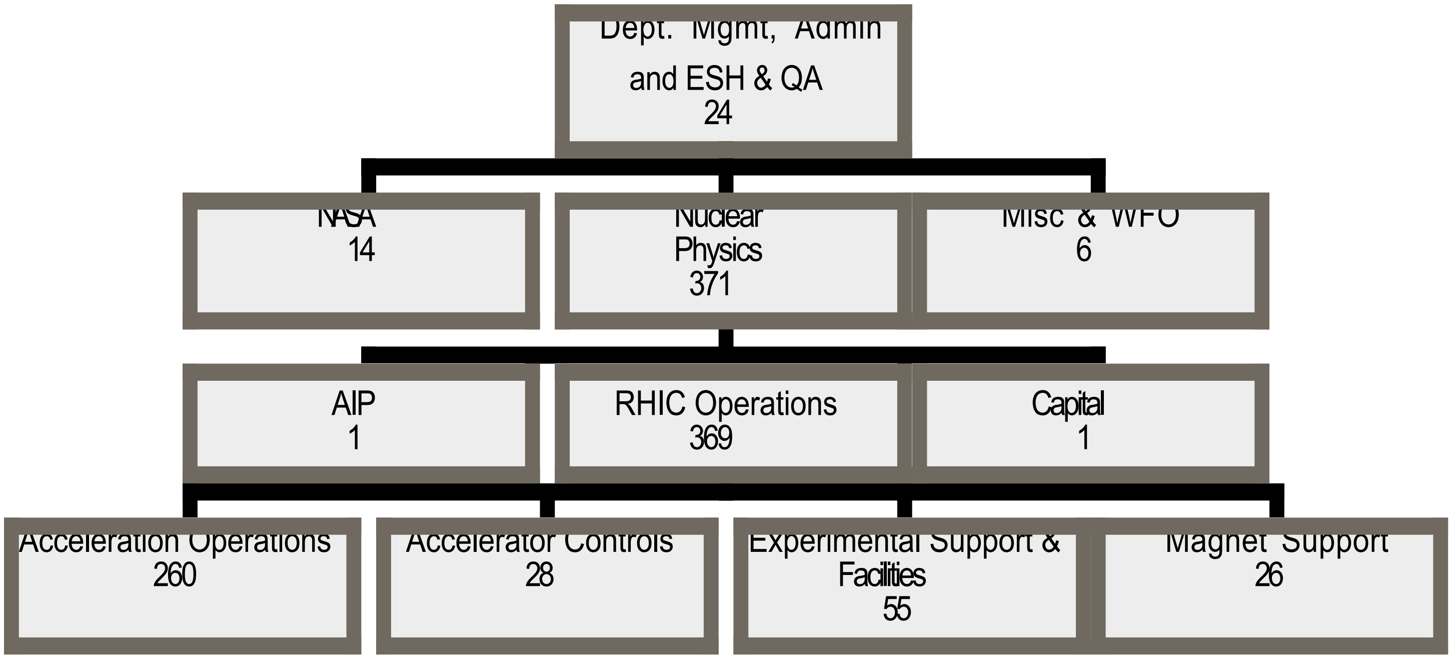
Facilities: Principal facilities of the Collider-Accelerator Department comprise

- Tandems (2), Linac, Booster, AGS, RHIC (2)
- 640,000 ft.^{2} accelerator areas
- 140,000 ft.^{2} experimental areas
- 173,000 ft.^{2} general office/laboratory space
- 149,000 ft.^{2} high-bay work space
- 87,000 ft.^{2} storage/materials handling space
- Research Library and 190 seat auditorium

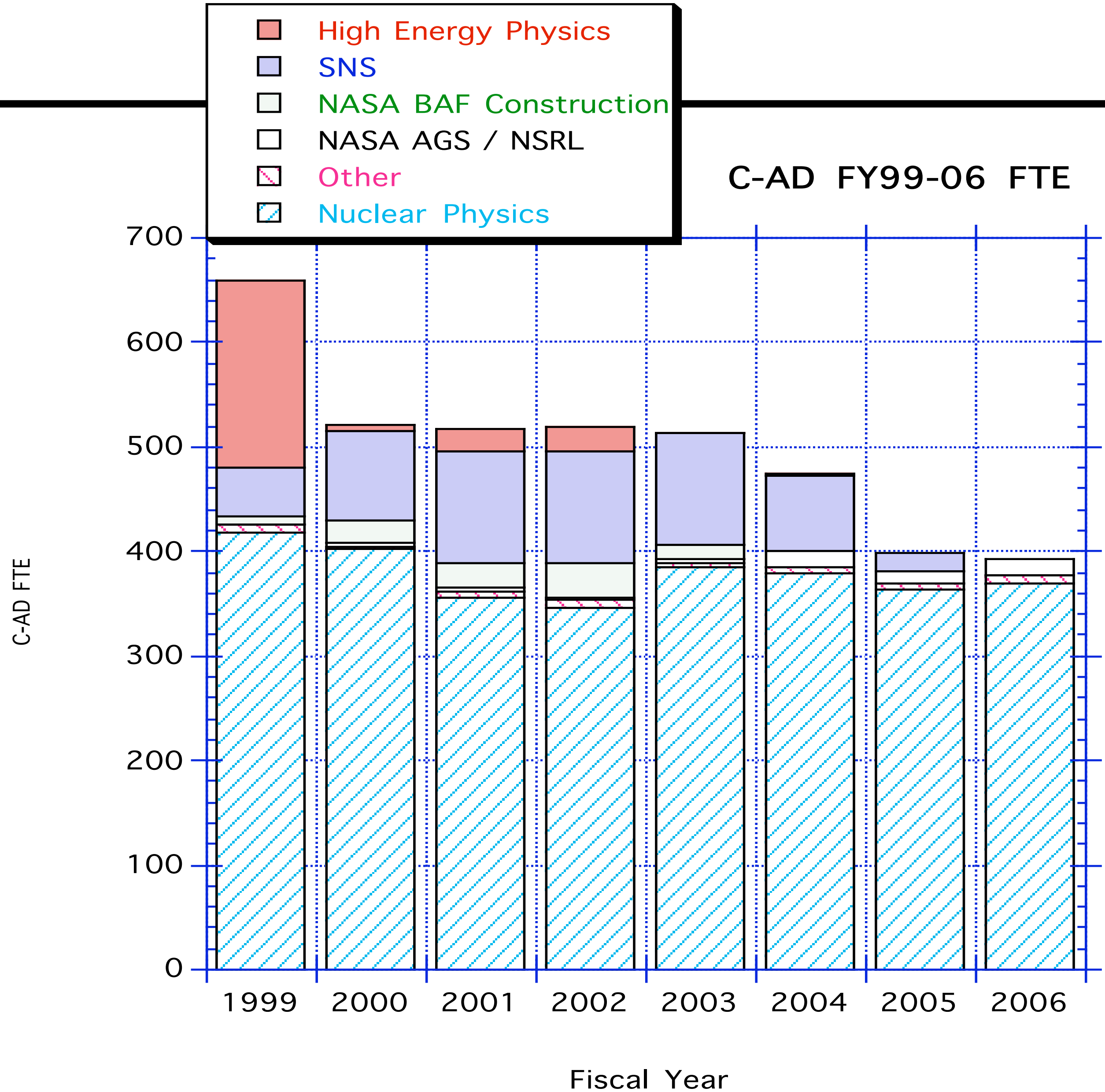

PHOBOS
10:00 o'clock
12:00 o'clock
BRAHMS & PP2PP ($\vec{p}$)
2:00 o'clock
RHIC
4:00 o'clock
PHENIX($\vec{p}$)
8:00 o'clock
STAR ($\vec{p}$)
6:00 o'clock
NSRL
μ g-2
HEP/NP(p)
LINAC
BOOSTER
AGS
TANDEMS

Collider - Accelerator Department

(Programmatic Heads 415)*



* Reflects Head data circa June 2005



High Energy Physics
SNS
NASA BAF Construction
NASA AGS / NSRL
Other
Nuclear Physics
C-AD FY99-06 FTE
C-AD FTE
700
600
500
400
300
200
100
0
1999
2000
2001
2002
2003
2004
2005
2006
Fiscal Year

FY05 Awards & Publications

FY2005 Awards

- NASA NSRL Recognition Award – D. Lowenstein and A. McNerney, November 2004
- 2005 IEEE-NPSS Particle Accelerator Science and Technology Award – T. Roser, May 2005
- BNL Environmental Stewardship Award – J. Scott, April 2005
- Russian Academy of Sciences Nuclear Physics Research Award – D. Kayran, April 2005

FY2005 Publications and invited talks (to date)

- 188 publications
  - 22 journal, 11 refereed
  - 155 conference proceedings
  - 11 reports
- ~10 invited talks

Funding: FY 2005 ($M to date)

Fund Type	DOE NP	SNS	NASA	Other	Totals
Operating	100.6	0.0	5.0	2.9	108.5
Equipment	1.5	0.0	0.0	0.0	1.5
Construction/AIP	3.1	5.4	0.0	0.0	8.5
Totals	105.2	5.4	5.0	2.9	118.5

C-AD ES&H Performance Indicators

	2004	2005
Whole-Body Collective Dose (person-rem)[2]	5.28	**~2.0**
Skin and Clothing Contaminations	0	**0**
Internal Contamination	0	**0**
Radioactive/Hazardous Materials Overexposures	0	**0**
Days Away and Restricted Day Rate (# per 100 FTEs)	1.7	**0.66**
1.Cases	7	**1**
1.Total Hours Worked in Year (1000s)	826	**~359**
Recordable Injury/Illness Rate (# per 100 FTEs)	2.9	**1.31**
1.Cases	12	**2**
First Aid Cases Excluding Athletic Injuries	5	**1**
Unplanned Safety Function Actuations	0	**0**
Violations of Operating Procedures	0	**0**
Unplanned Shutdowns	0	**0**
Occurrences	7	**2**
Environmental Related Occurrences	0	**0**
Solid Low-Level Waste Shipped		
1.Radioactive Waste (cu-ft)	2400	**3566**
1.Hazardous Waste (cu-ft)[3]	200	**8.2**
1.Mixed Waste (cu-ft)[3]	35	**181**
1.Industrial Waste (cu-ft)[3]	700	**143**

2005 C-AD Reportable Ocurrences

2005, Employee Falls While Walking
2005, Slip and Fall Results in Hairline Fracture of Kneecap

FY2006 Budget Issues:

President's budget was a disaster. Congressional budget greatly improved. What will Congress ultimately provide after the rescissions?

- **DOE unfunded infrastructure mandate** forces increased space charge rate at 9.8% each year from FY05-FY07
  - Increased space charge reduces available operating funds by $1M in FY2006, on top of the $1M in FY2005
  - SNS manpower has been a shared resource with the RHIC program. 65 FTE reduction in FY2005 completed. No longer available to support NP.
  - Reduced SMD manpower support to 26 FTE from 35 FTE
- **New NYPA power rates go into effect in July 2005.**
- Average power rate expected to be $65 / MWH, up from $55 / MWH
- **e-cooling grow to $3M to keep on schedule. (see Ben-Zvi talk)**

C-AD Program Areas

RHIC

- Heavy Ion (DOE-NP).
- Polarized Proton (DOE-NP).

AGS

- Radiobiology (NASA, conjunction with NSRL).

Tandem

- Commercial Users ($1M yearly sales).

Linac

- Isotope Production (DOE-NE, *problematic, parasitic on linac operations).*

Booster

- NASA Space Radiation Laboratory (NASA, $5.5M/year, incl. $2M for Medical and Biology Departments).

C-AD Program Areas

Projects

- Spallation Neutron Source (DOE-BES, completed, $118M)
  - Accumulator ring and beam lines: delivered on schedule, below estimated cost
- Electron Beam Ionization Source injector (DOE-NP + NASA, CD1 under preparation,$19M)
- RSVP (NSF HEP, $50M construction,$12M/year ops).
  - Decision expected mid-August
- NSRL facility expansion (under discussion)
- Neutrino proposal (DOE HEP under development)
- Hadron therapy facility, interest from several sources, but no funding yet

EBIS Project

Joint DOE and NASA Project

Replace Tandems

- Improved beam intensity
- Allow for masses to uranium and noble gases
- Lower operating costs

First step in project approved by DOE

- CD0; Mission Need

Second step, CD1, is underway

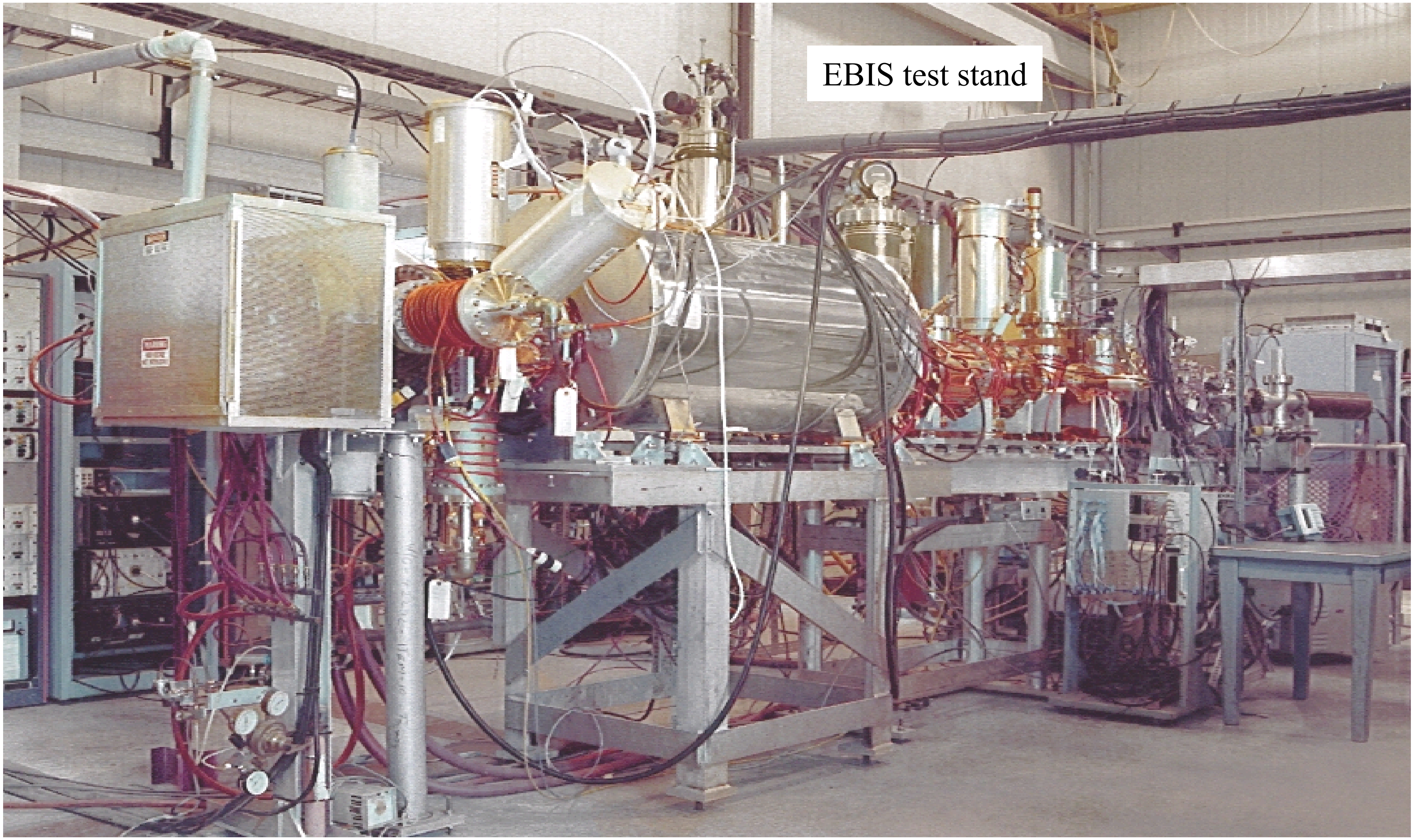
- DOE CD1 technical, cost and schedule base-line review (7/25-27)

NASA has agreed to support $4.5M of cost

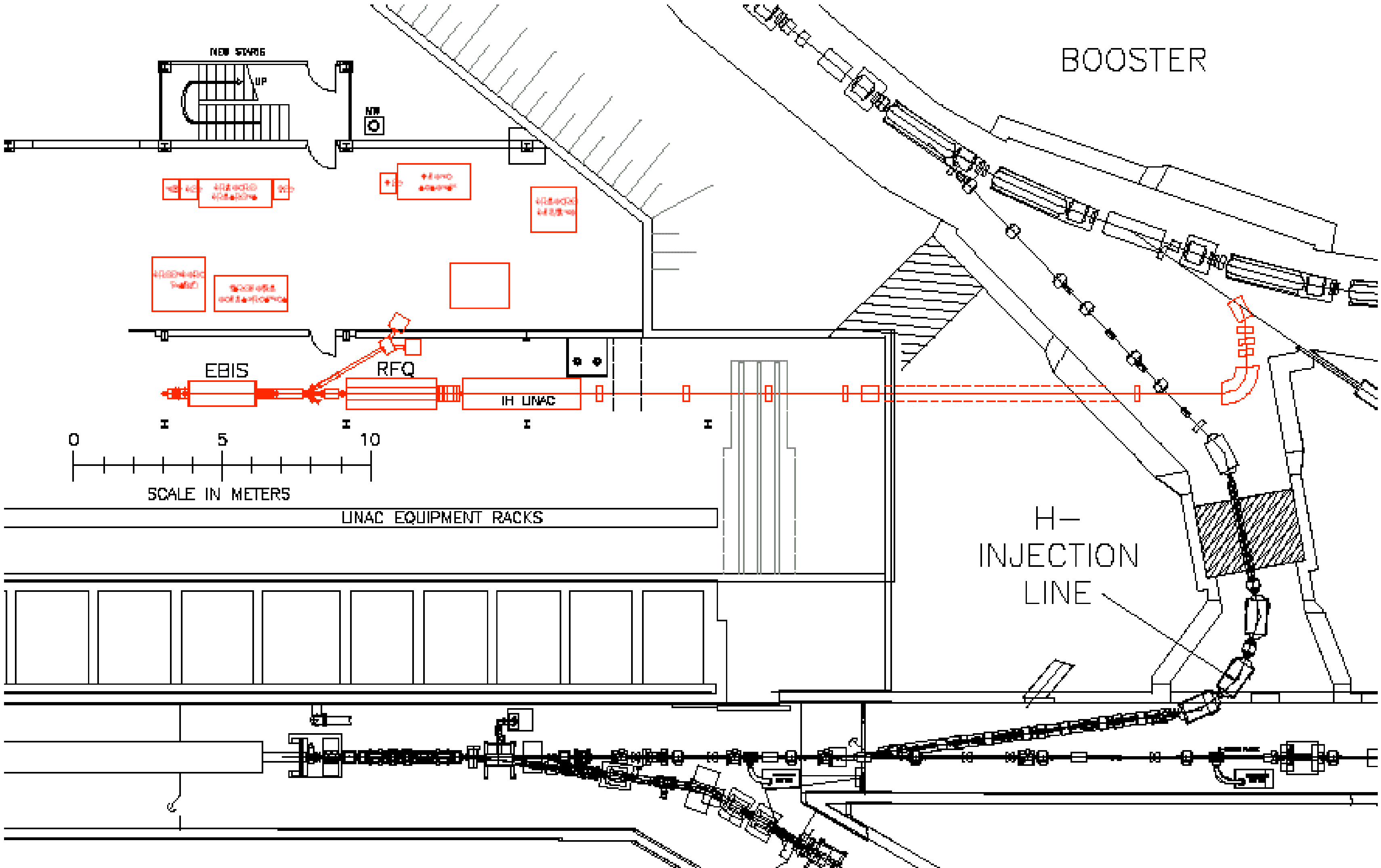
  - First funds have arrived at BNL

~$19M to build EBIS, RFQ and Linac

Commissioning in FY2009


EBIS test stand

RHIC EBIS Injector Layout



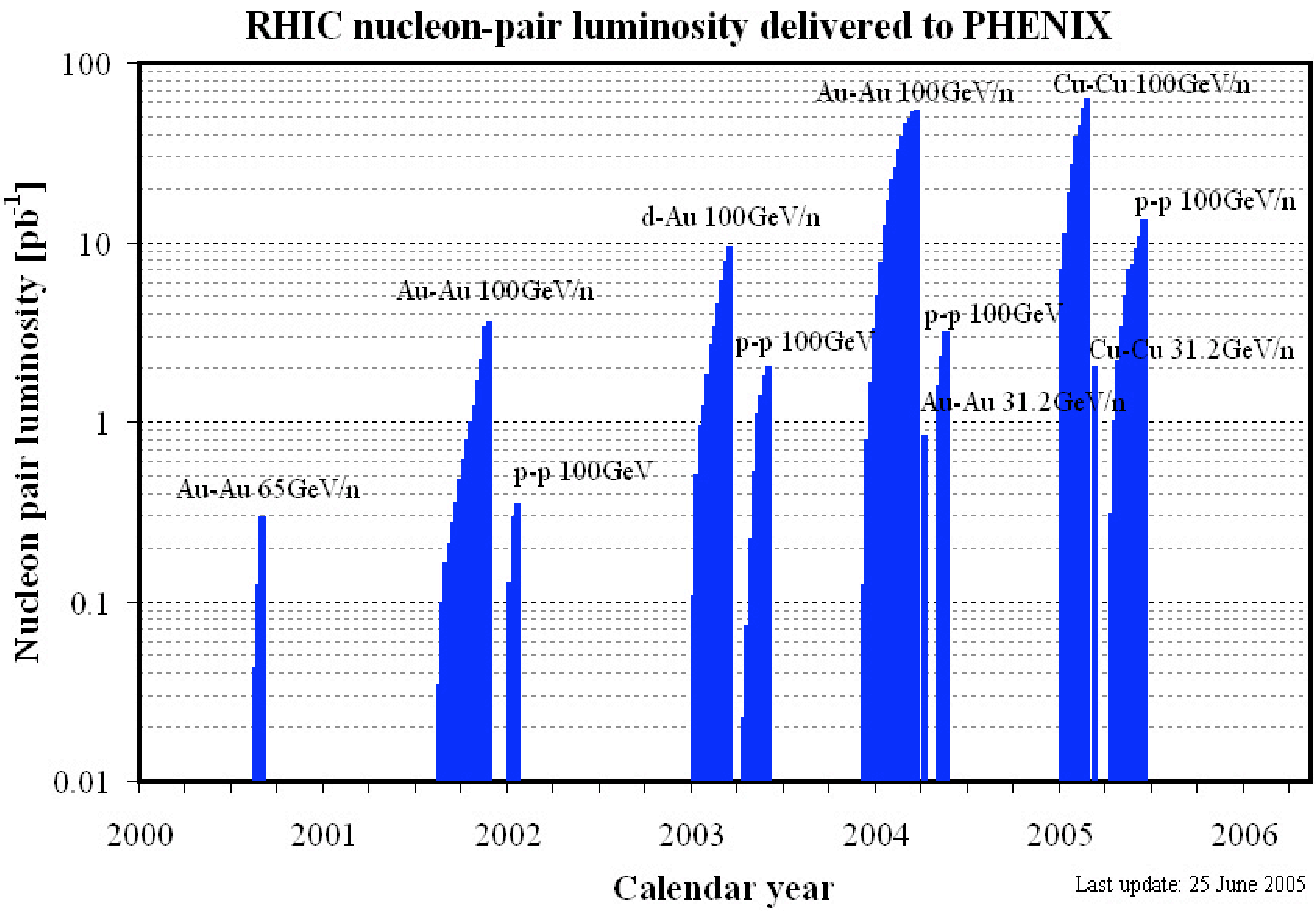
R&D

- electron-cooling of ions(DOE NP, BNL PDF, US Navy, AES, JLab). See Ilan Ben-Zvi presentation
  - Significant physics understanding over the past year
  - US Navy interest in 100 KW FEL
    - ERL linac could be used for cooling
- stochastic - cooling of RHIC ions
  - Beam studies continue, first indications that cooling will work
- eRHIC design (MIT-Bates, Novosibirsk)
  - ZDR completed, 2 designs under consideration
- Polarized He3 source
  - Expect MIT-Bates, Caltech groups to submit R&D proposal

RHIC Performance

RHIC: unlike any other collider

1. Greater operational flexibility than other hadron colliders
   - Variation in particle species, also asymmetric
     → So far Au+Au, d+Au, p+p, Cu +Cu
   - Variation in energy
     → Au+Au at 11, 31, 66, 100 GeV/u
   - → Cu+Cu 11, 31, 100 GeV/u
     → p↑+p↑ at 100, 205 GeV
   - Variation in lattice
     → Low β^* in most cases (.85-3 m)
     → Large β^* for small angle scattering experiments (>10 m)
     → Polarity change in some experimental magnets
   - Variation bunch to bunch polarization patterns
2. Four experiments (2 large, 2 small), different preferences
   - Need to avoid that any one experiment becomes bottleneck
3. Short runs (~30 weeks/year), with multiple modes
   - Significant amount of set-up time required
4. Short luminosity lifetime with heavy ions (~ few hours)
   - Fast refills essential



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RHIC design and achieved parameters

Mode	No of bunches	Ions/bunch $[10^9]$	β^* [m]	Beam pol.	$L_{store\ ave}$ $[cm^{-2}s^{-1}]$	$A_1A_2L_{store\ ave}$ $[cm^{-2}s^{-1}]$	$A_1A_2L_{peak}$ $[cm^{-2}s^{-1}]$
			Design values (1999)				
Au – Au	56	1.0	2		2×10^{26}	8×10^{30}	31×10^{30}
p – p	56	100	2		4×10^{30}	4×10^{30}	5×10^{30}
			Achieved values (up to 2005)				
Au – Au	45	1.1	1		4×10^{26}	16×10^{30} (2)	58×10^{30}
d – Au	55	120/0.7	2		3×10^{28}	6×10^{30}	24×10^{30}
Cu – Cu	36	4.5	1		80×10^{26}	32×10^{30}	79×10^{30}
p↑ – p↑	106	90	1	48%	8×10^{30}	8×10^{30}	10×10^{30}
p – p	56	170	1		10×10^{30}	10×10^{30} (2.5)	15×10^{30}

$$L = \frac{3 f_{rev}\gamma}{2}\frac{N_B N^2}{\varepsilon\beta^*}$$

Other high luminosity hadron colliders:

	achieved	goal	scaled to 200 GeV
Tevatron (2 TeV)	128×10^{30}	200×10^{30}	20×10^{30}
LHC (14 TeV)		10000×10^{30}	140×10^{30}

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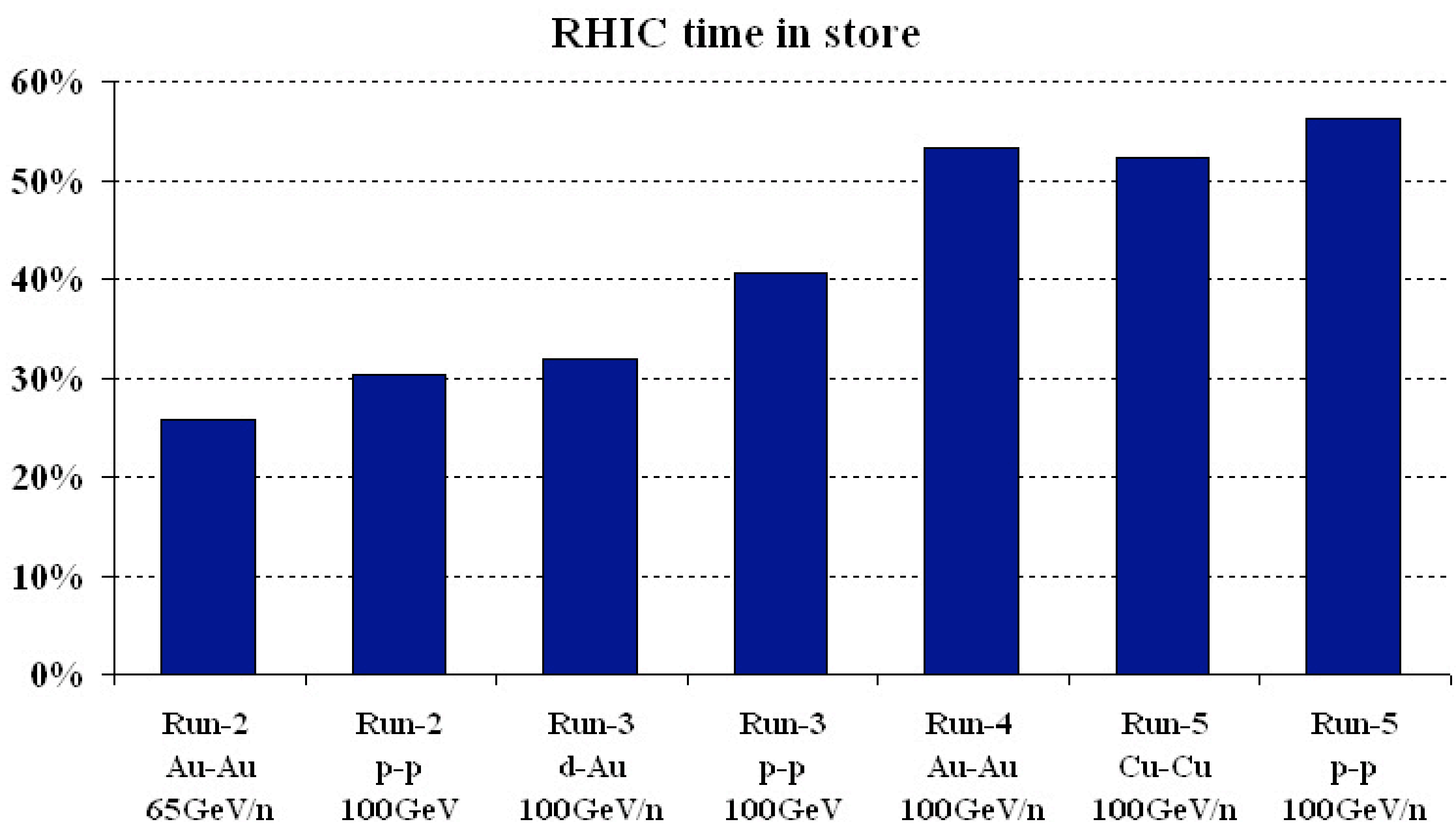
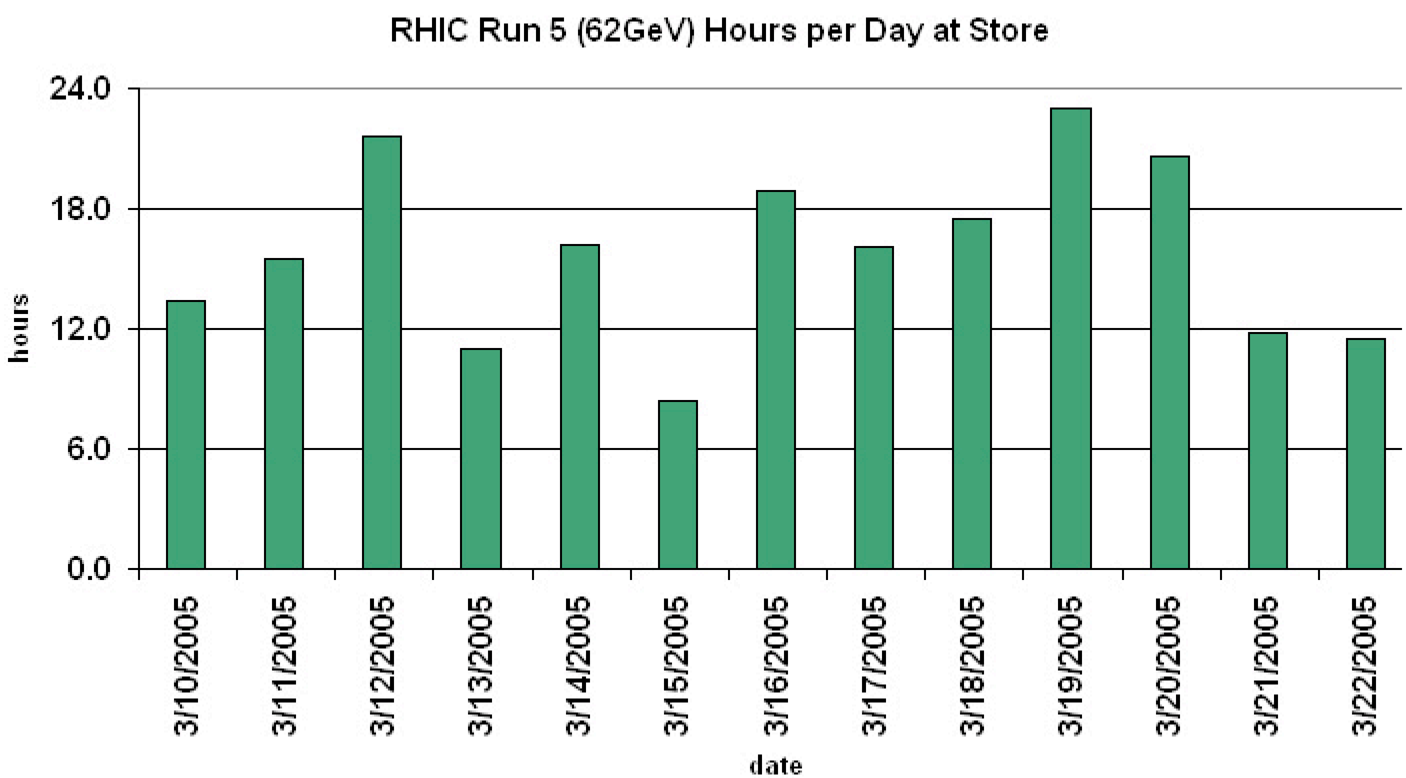
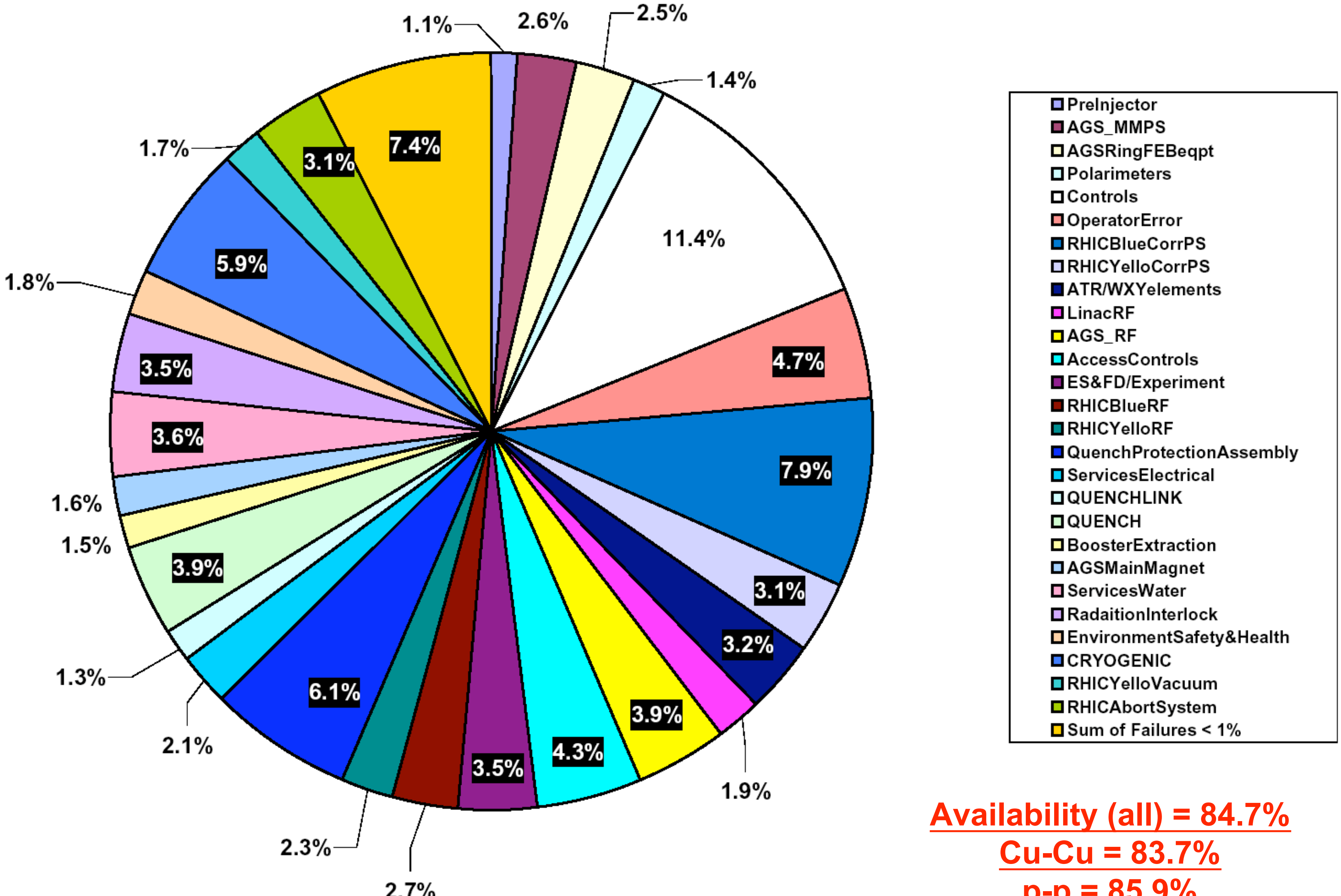


RHIC time in store
60%
50%
40%
30%
20%
10%
0%
Run-2 Au-Au 65GeV/n
Run-2 p-p 100GeV
Run-3 d-Au 100GeV/n
Run-3 p-p 100GeV
Run-4 Au-Au 100GeV/n
Run-5 Cu-Cu 100GeV/n
Run-5 p-p 100GeV/n

Hours at store - low energy Cu



RHIC Run5 System Failures as a fraction of the Total 694 failure hours



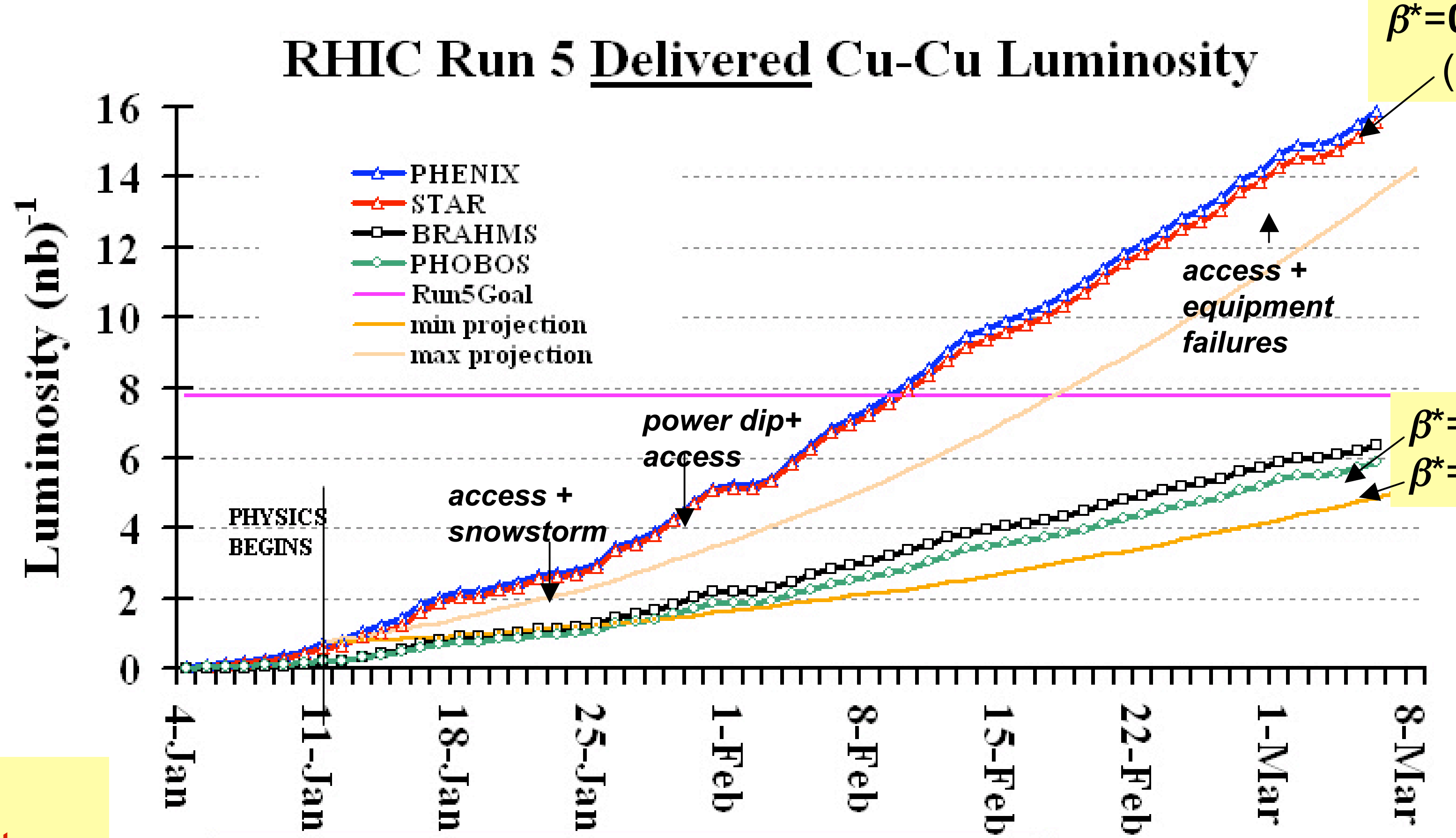
Availability (all) = 84.7%
Cu-Cu = 83.7%
p-p = 85.9%

No system stands out as particularly problematic
Control system is radiation damage to front-end processors

Cu-Cu overall results-see Todd Satogata presentation

- Delivered 15 nb^{-1} in the 100 GeV/u run, more than twice the goal of 7 nb^{-1}
- Exceeded maximum luminosity projections
- Set&ramp-up time with beam 2.5 weeks (4 weeks planned)
- All experiments had a successful run
- Successful 2 weeks at 31.2 Gev/u, set-up 2 days
- Successful 1 day run at injection 11 GeV/u

Integrated luminosity 100 GeV/u



calendar time at store: **52%**

Cu-cu cross section measured at 2.6 barn

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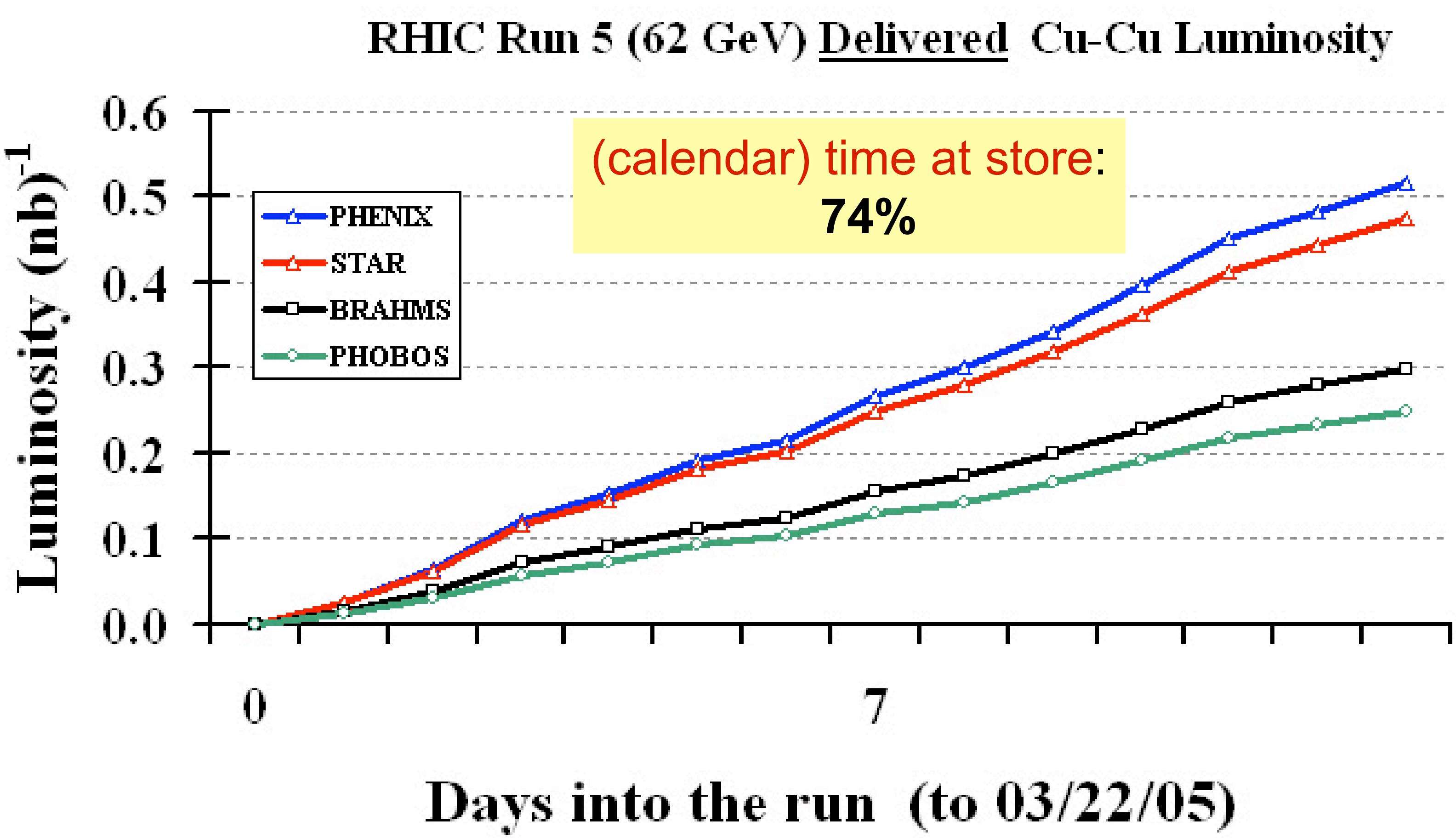
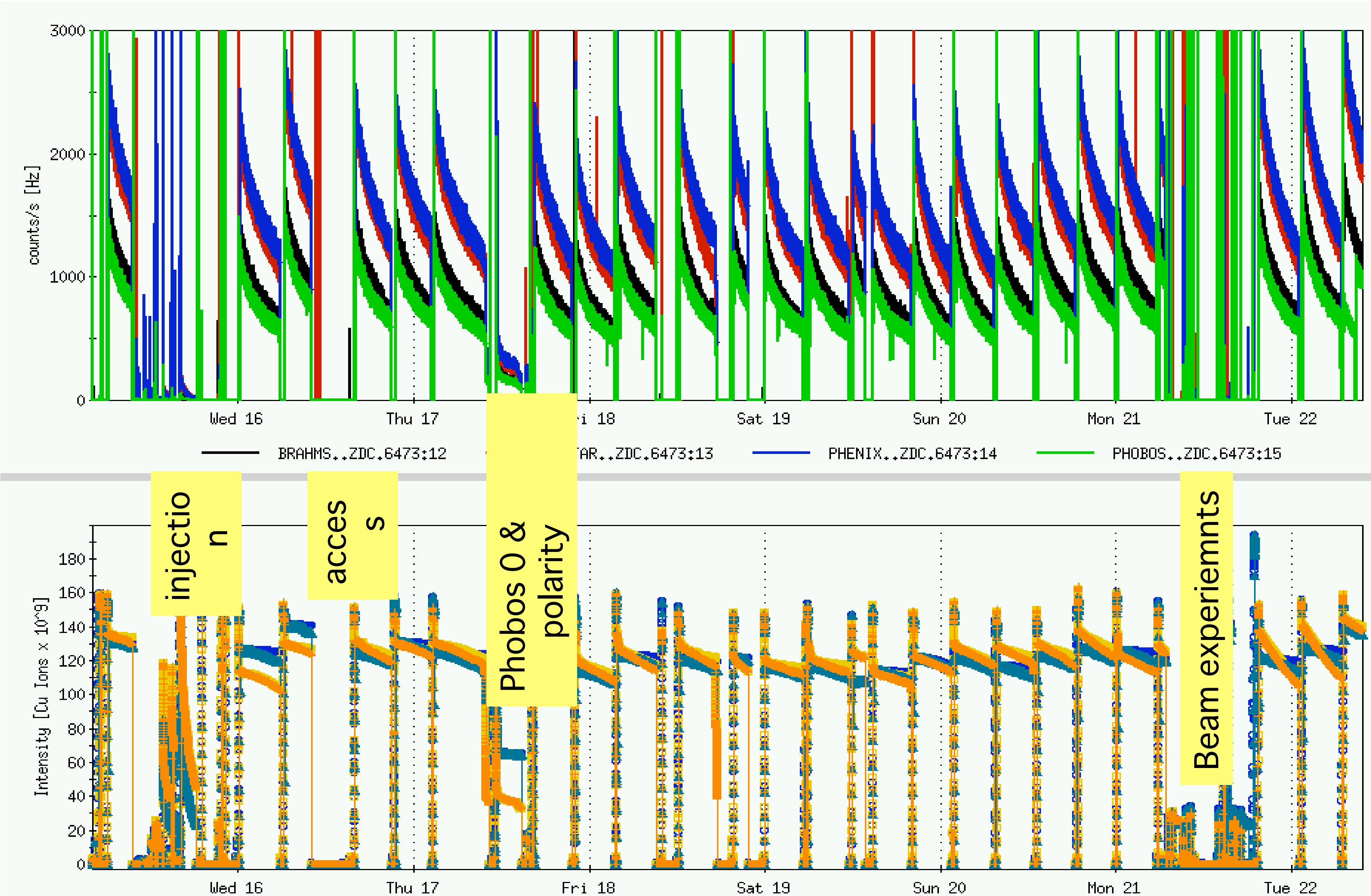
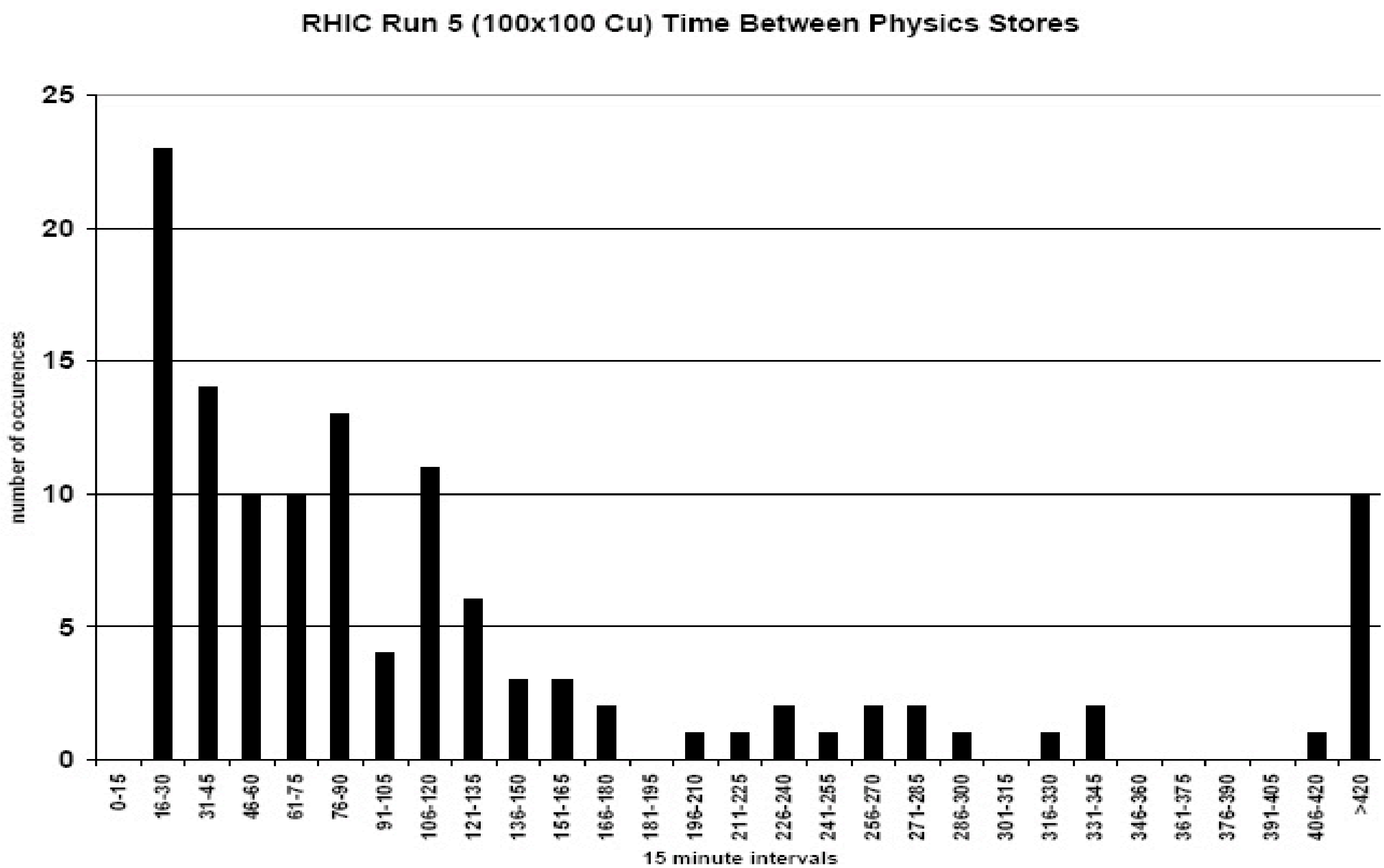
Integrated luminosity 31.2 GeV run



31.2 GeV / u Run - week 2 - stores



100 GeV/u Cu-Cu time between stores



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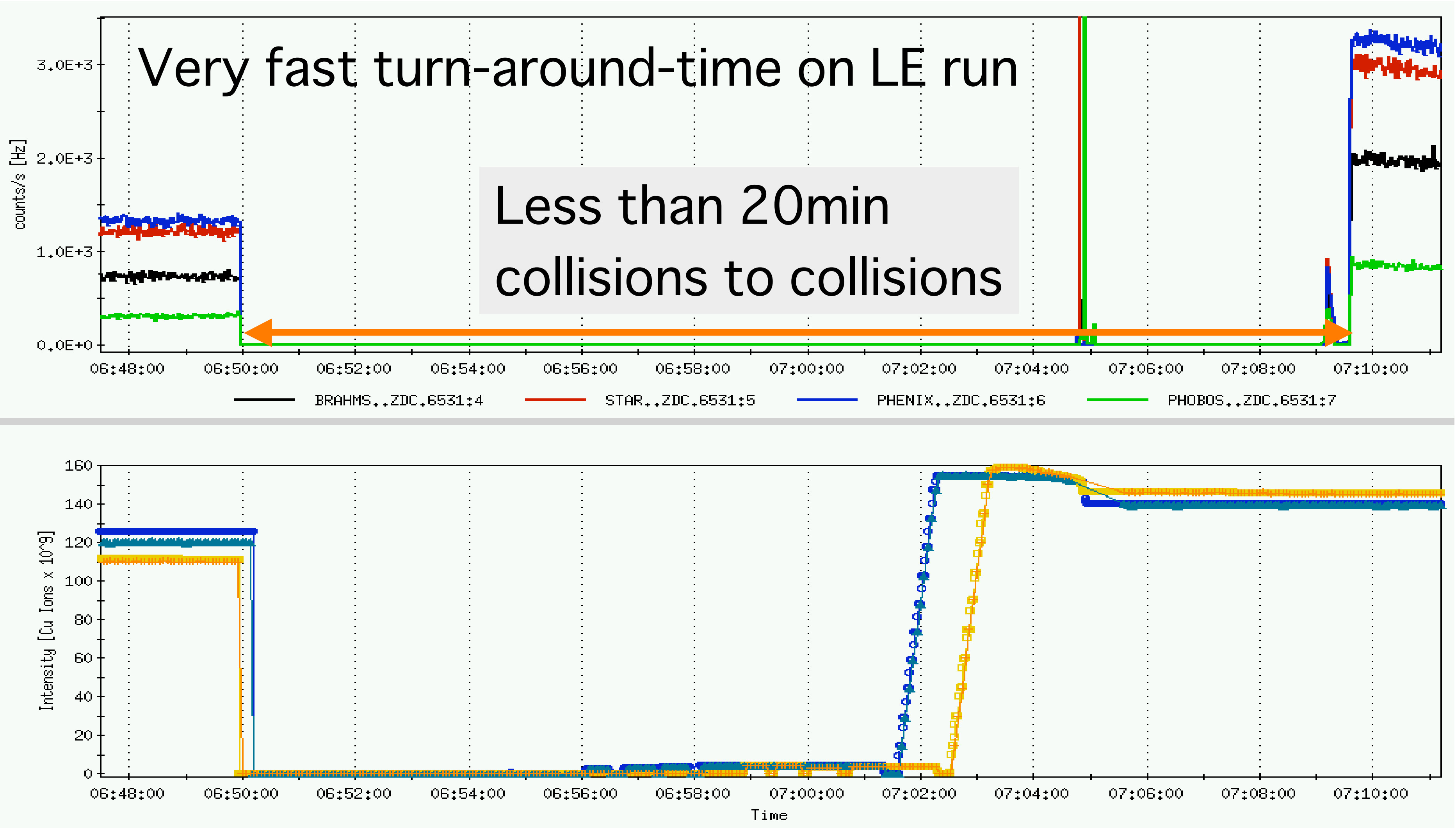
31.2 GeV / u store-to-store time



RHIC pp -see Mei Bai presentation

100 GeV/u for experiments STAR, PHENIX and BRAHMS

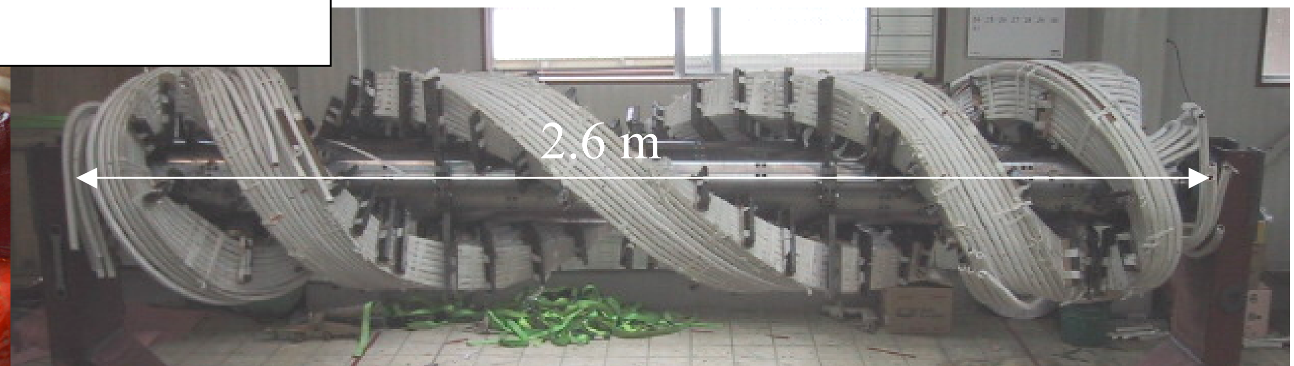
- Greatly improved luminosity and polarization performance
- Provided both longitudinal and transverse polarized beam
- Superconducting partial Siberian Snake in AGS was commissioned and expected to be used in Run 6
  - Open questions will be studied during next run
- Successfully accelerated/collided 111x111 bunches @ .75 x 10^{11} per bunch from the previous 56 x 56 @ .75 x 10^{11} per bunch

Beyond 100 GeV/u

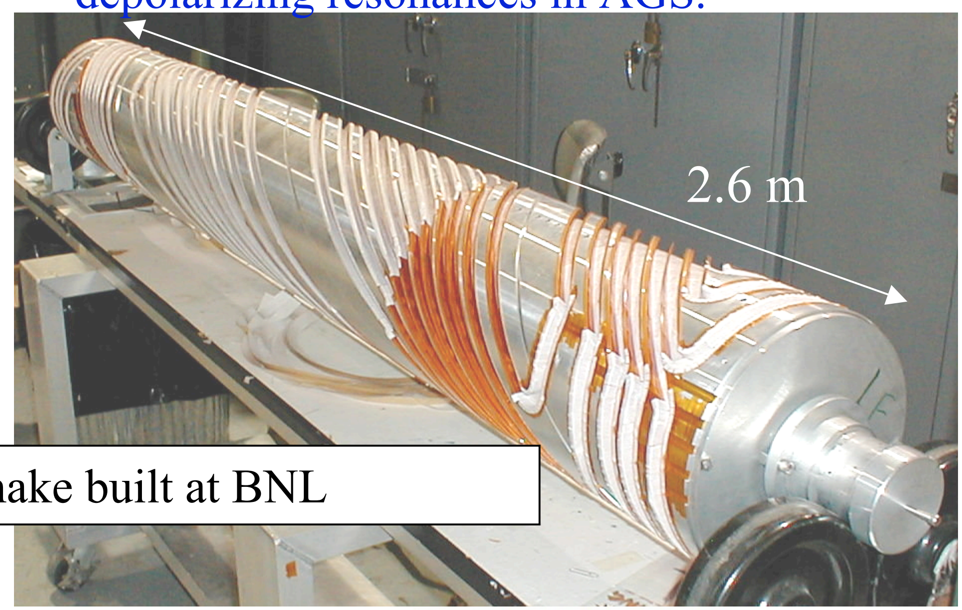
- Beams were accelerated and collided at 205 GeV/u as a test
  - 30% polarization immediately measured in both rings at 205 GeV/u

New AGS helical snakes

6 % helical snake built at Tokana Industries
Funded by RIKEN.

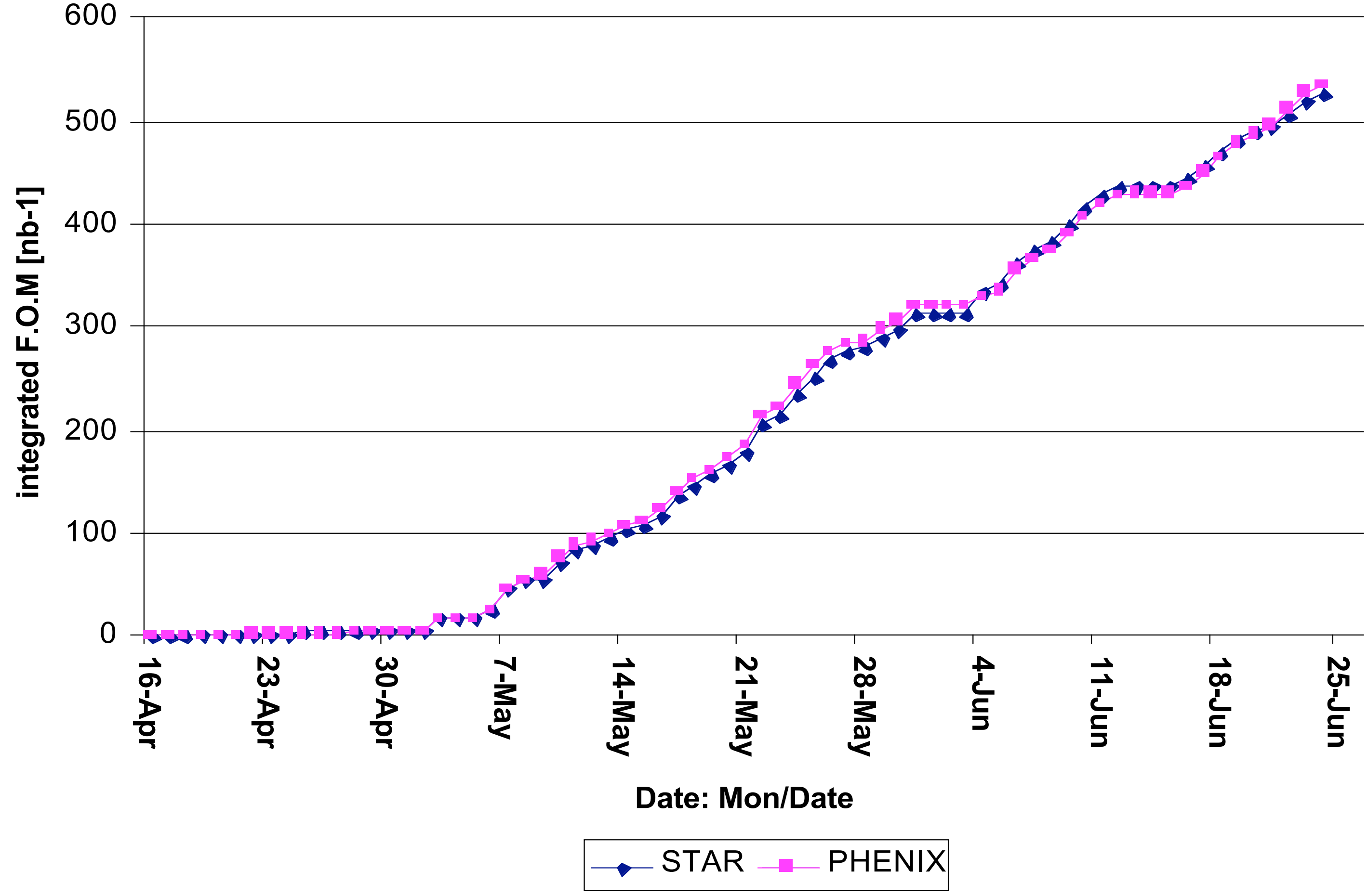


- Warm snake avoids polarization mismatch at AGS injection and extraction.
- Cold strong snake eliminates all depolarizing resonances in AGS.



25% s.c. helical snake built at BNL

RHIC pp figure of merit ($P_B^2 P_Y^2 L$) delivered



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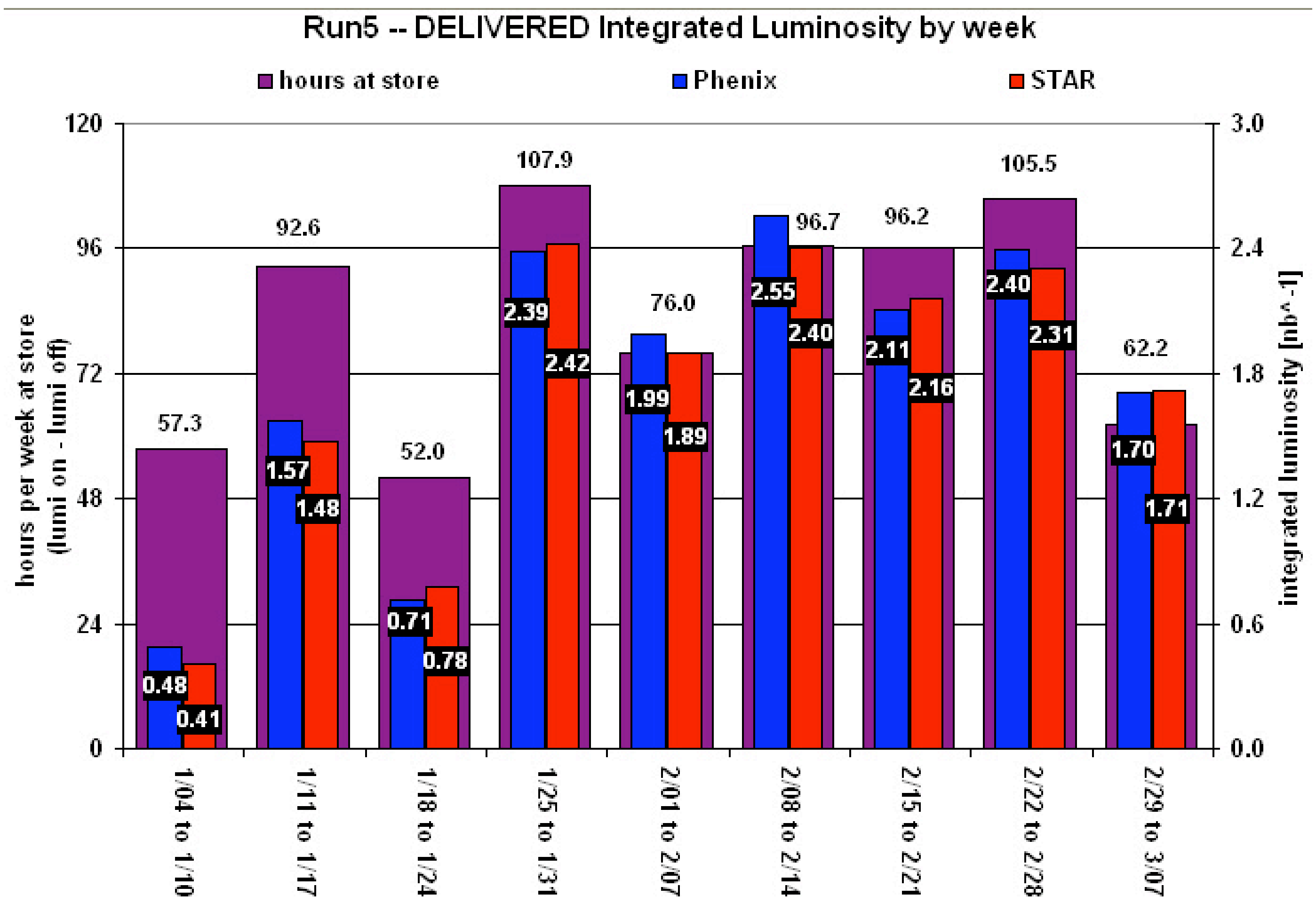
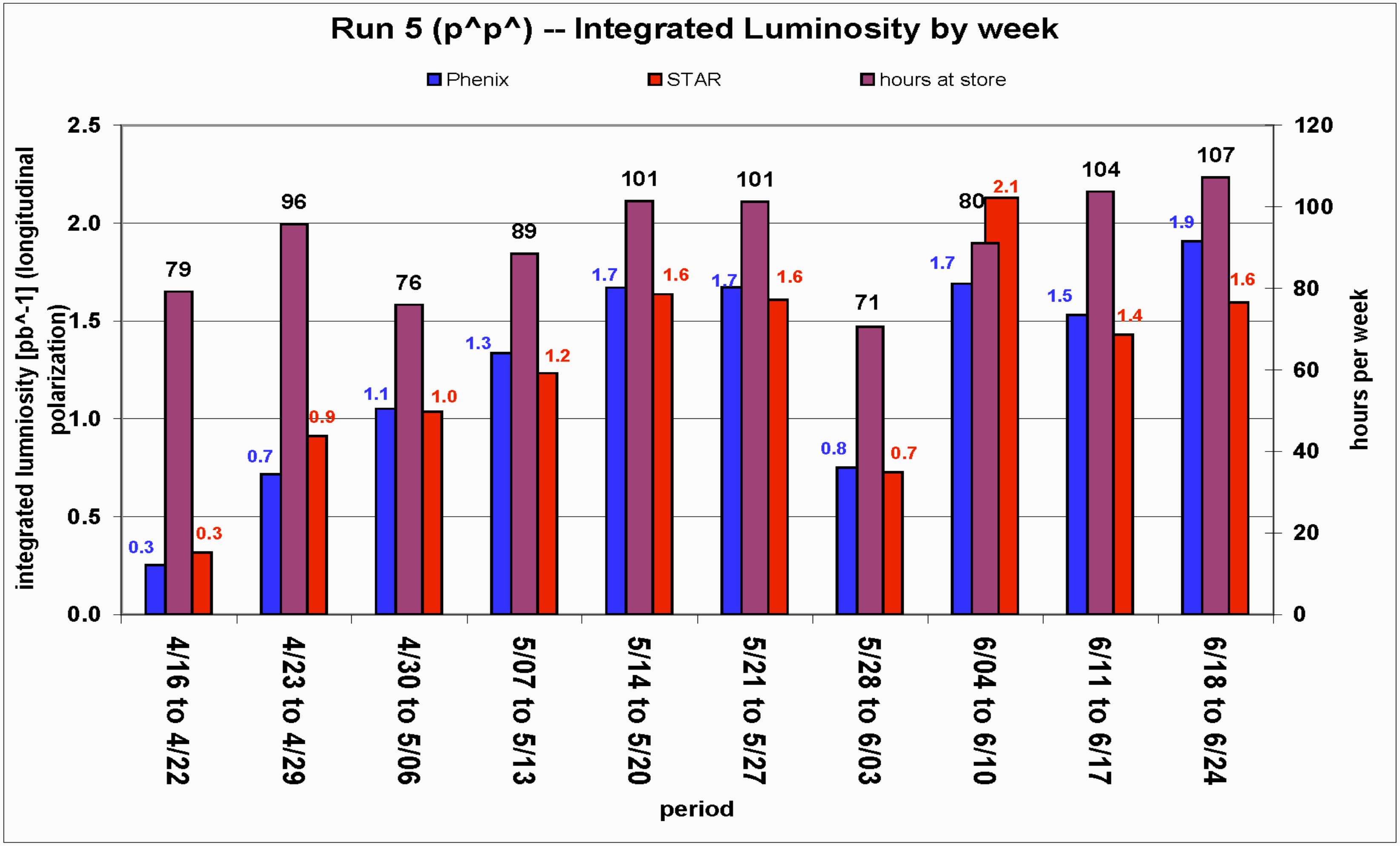
FY2005 RHIC operations was again outstanding

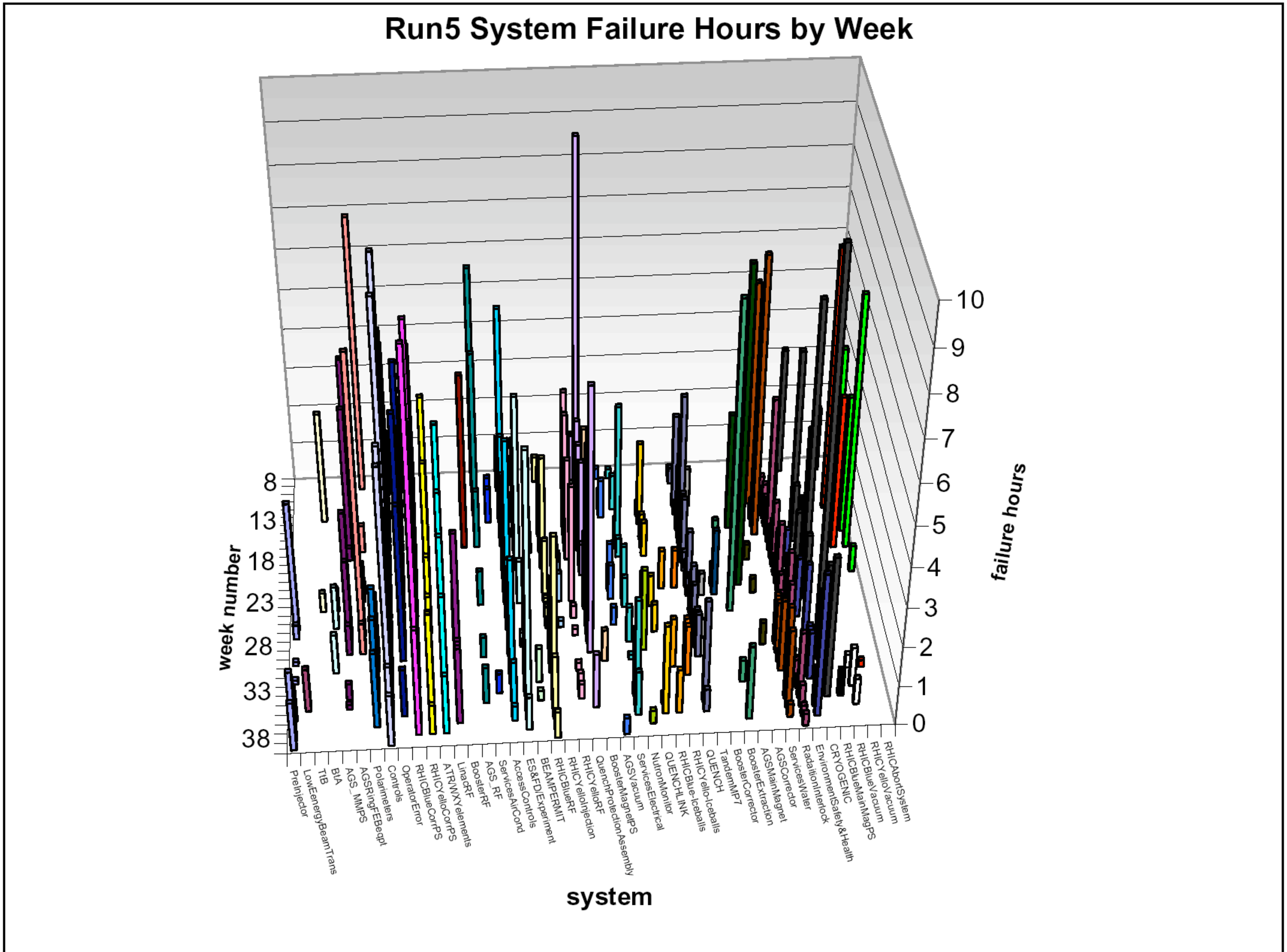
Additional Material

Cu-Cu Luminosity / week





Run 5 (p^p^) -- Integrated Luminosity by week
Phenix
STAR
hours at store
integrated lumniosity [pb^-1] (longitudinal polarization)
hours per week
period
0.0
0.5
1.0
1.5
2.0
2.5
0
20
40
60
80
100
120
4/16 to 4/22
4/23 to 4/29
4/30 to 5/06
5/07 to 5/13
5/14 to 5/20
5/21 to 5/27
5/28 to 6/03
6/04 to 6/10
6/11 to 6/17
6/18 to 6/24
0.3
0.3
79
0.7
0.9
96
1.1
1.0
76
1.3
1.2
89
1.7
1.6
101
1.7
1.6
101
0.8
0.7
71
1.7
2.1
80
1.5
1.4
104
1.9
1.6
107



Run5 System Failure Hours by Week
week number
8
13
18
23
28
33
38
failure hours
0
1
2
3
4
5
6
7
8
9
10
system
PreInjector
LowEnergyBeamTrans
TtB
BtA
AGS_MMPS
AGSRingFEBeqpt
Polarimeters
Controls
OperatorError
RHICBlueCorrPS
RHICYelloCorrPS
ATRWXYelements
LinacRF
BoosterRF
AGS_RF
ServicesAirCond
AccessControls
ES&FD/Experiment
BEAMPERMIT
RHICBlueRF
RHICYelloRF
RHICYelloInjection
QuenchProtectionAssembly
BoosterMagnetPS
AGSVacuum
ServicesElectrical
NutronMonitor
QUENCHLINK
RHICBlue-Iceballs
RHICYello-Iceballs
QUENCH
TandemMP7
BoosterCorrector
BoosterExtraction
AGSMainMagnet
AGSCorrector
ServicesWater
RadiationInterlock
EnvironmentSafety&Health
CRYOGENIC
RHICBlueMainMagPS
RHICBlueVacuum
RHICYelloVacuum
RHICAbortSystem